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Alveolar Distraction Osteogenesis: A Review

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Dr. M. Jagruthi, † Dr. Sandeep Kumar, †† Dr. Rajnish Aggarwal, ††† Dr. Vinutna Uppalapati, * Dr. Saiba Khan, **

† Post Graduate, Department of Prosthodontics, Surendera Dental & Research Institute, SriGanaganagar, Rajasthan, India

†† Professor & Head, Department of Prosthodontics, Surendera Dental & Research Institute, SriGanaganagar, Rajasthan, India

††† Professor, Department of Prosthodontics, Surendera Dental & Research Institute, SriGanaganagar, Rajasthan, India

* Post Graduate, Department of Prosthodontics, Surendera Dental & Research Institute, SriGanaganagar, Rajasthan, India

** Post Graduate, Department of Prosthodontics, Surendera Dental & Research Institute, SriGanaganagar, Rajasthan, India

Corresponding Author: Dr. Sandeep Kumar

E-mail: mdssandy07@gmail.com Contact No: 9024606318

Address: Surendera Dental College and Research Institute, H.H.Gardens, Sadulsahar Road, Sriganganagar, Rajasthan, India-335001

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Abstract

Dr. Gavrial Ilizarov is considered as the father of distraction osteogenesis. There have been newer developments in the field of distraction osteogenesis for amelioration of deformities. The further development in this region, has also helped in preparing the area for implant placement. In this article, we will be learning about alveolar distraction osteogenesis in general.

1. Introduction

Distraction osteogenesis is a biological process wherein new bone is lay down between the surfaces of bony segments which have been separated from each other by the process of traction in increments. It is established on the principle of "tension- stress". As the traction in bone starts, it results in generation of tension at that particular site which further triggers new bone formation wherein the bone lay down is parallel to the vector of distraction.[1,2]

For formation of new bone and intercepting any sort of early ossification or fibrosis, distraction is based on the principle of latency, surgical procedure, rate, rhythm, stabilisation and consolidation. For rejuvenating favourable soft as well as hard tissue, indication of alveolar distraction has to be followed properly.

Distraction osteogenesis procedure was first elucidated by Codivilla[3] in the year 1905 wherein he described the osteotomy of the femur to elongate the bone by using sudden intense pull.

Putti[4] in the year 1921 described that by use of Kirschner wires for the elongation of the femur. Abbot[5] advocated the step osteotomy procedure in concomitance with pins wherein the length of the bone increased by the mechanics of that in compressed spring in 1927.

Illizarov[6] is considered to be the father of distraction osteogenesis as he described the basis of distraction. He was a proponent who advised the use of corticotomy and as well as the preservation of both periosteal and medullary blood supply. He also advocated that after the latency period of around 5-7 days 1mm per day of slow bone expansion has to be carried out. McCarthy[7] in 1992 delineated the

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very first case of distraction by correcting hemifacial microsomia in the maxillofacial region of the mandible.

2. Biology

Illizarov[1,2,6] was the first to describe the biological basis for distraction gap healing. There was gap formation which was seen after the activation of the distractor device following the osteotomy. Formation of the regenerate was seen between the bony segments after the gap formation on expansion.

There are four standard zones which can be seen on histological examination (fig.1) : (a) zone of fibrous tissue- type 1 collagen fibres develop in the center and are arranged parallel to each other, in the regenerate region (b) zone of extended bone formation, present on either sides of zone of fibrous tissue formation wherein it contains mesenchymal cells and osteoblastic cells; (c) zone of bone remodelling, seen neighbouring to the zones of mature bone and displays active osteoblastic and osteoclastic activity; (d) zone of mature bone, detected at the borders of the osteotomy segments, with bone spicules bridging the regenerate to the osteotomized bone edges.[8]

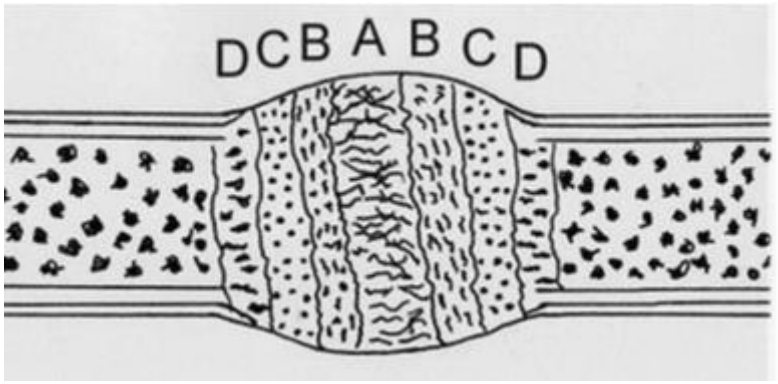

Figure. 1. regions of regenerate. A, fibrous tissue region ; B, new bone emergence region; C, bone remodelling region; D, mature bone region

The beginning stages of healing involved in distraction procedure are indistinguishable to that seen in fracture healing. A soft callus is sustained in the central region of regenerate and in the boundary region, fracture healing takes place. Thus, with distraction, the different steps in fracture healing occur in continuity rather than being consecutively. The sequence of steps in healing have been narrated as redness and swelling, soft callus formation, gradual traction of the soft callus, hard callus formation, and remodeling.[9]

The first phase is seen to be lead by fibrin clot formation which fills up the osteotomy site and terminates around 3rd day, called as inflammatory stage (fig.2). Soon the fibrin clot is replaced by the granulation tissue and later on there in increase in the capillary formation. As the day progresses, the fibrous tissue restores the region which was previously occupied by the granulation tissue, at the peripheral regions there is bone or cartilage formation forming the soft callous. Around 10th day after distraction, it is seen that the gap which as formed initially is now filled with collagen fibers that are arranged parallel to the direction of distraction. Fine bony trabeculae are seen extending into the collagenous matrix at the perimeter. It is seen that during this period the central region is barren of bony tissue. Osteoblastic and osteoclastic activities are seen after 14 days following distraction with slender trabeculae showing remodelling. Later on, the trabeculae become thicker and reaches the center of the gap and forms the osseous union. New bone formation is seen in the entire regenerate region around 28th day following distraction. Density of the regenerate region is increased by continuous remodelling and also due to increase in the quantity of mature lamellar bone.[8-12]

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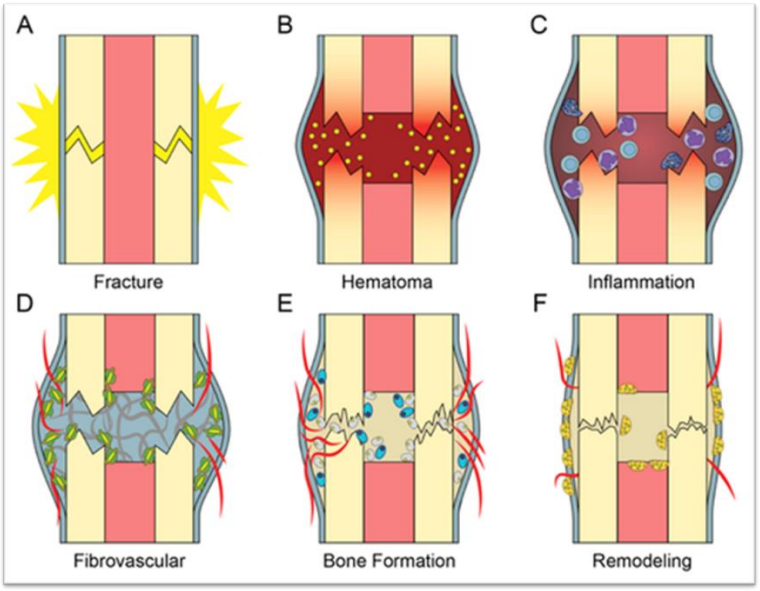

Figure.2- stages of fracture healing

Gaggl et al[13] harmonized the clinical, photographic images, and microscopic anatomical findings in a deflected bony segment with time, using two implant distractors. A month later, modest amount of radiopacity can be observed in the slot region formed due to distraction. On histological examination it was seen that there was large quantity of collagen fibers and soft tissue present. The central region shows minute traces of chondroid bone with generous amount of mesenchymal ossification. During the second month, radiopacity increases and there is decline in collagenous fibrils with an elevation in osteoid content and initial indication of lamellar calcification are also noted. By the end of 3rd month there is increase in radiopacity due to lamellar bone which extends up to the central region and also there is continuous remodelling of the lamellar bone with scarce display of all the fibrils. At the end of 6th month uniform radiopacity is seen.

3. Phases of Distraction

Four definitive stages are seen in distraction osteogenesis procedure. (fig.3)

(1) Dormancy period

The dormancy period is the time from surgery to initiation of distraction. Numerous studies conducted by various authors stated that the latency period ranges from rapid distraction by Wagner [14] to a period of 14 days by De Bastiani et al[15]. It was seen in various studies that there was enhanced quantity of fibrous tissue formation and decrease in quantity of bone density following immediate distraction. When the dormancy period was around 7 days its seen that there is increase in callous formation. There is increased capillary ingrowth as well as osteoblastic activity resulting in surge in new bone formation. In younger individuals and in case of least surgical trauma in grown-ups, a dormancy period of about 2-5 days was proposed. In case of geriatric person or in case of exacerbated surgical wound, at least a dormancy period of 7 to 14 days was advocated.[1,2,16,17]

(2) Distraction period

- Distraction rate is the proportion of length of the bone increased every single day. It was observed that when the amount of rate is below 0.5 mm/day there is a risk of early calcification, whereas a distraction rate is 2.0 mm/day this results in enhanced fibrous connective tissue formation and decrease in bone quantity. Hence, a rate of 1 mm/day is ideal for generation of bone.[1,2,18,19]

- Distraction rhythm is the number of cycles of distraction daily. Ilizarov[1,2] reveals that paramount of new vessels that circulate fluids and bone formation as well as reduced amount of soft tissue trauma can be seen with continuous force application. when the rhythm is increased to multiple series per day it reduces the amount of

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injury caused to the soft as well as hard tissue and thus enhances patient comfort. Hence, a speed of 0.25 mm qds or 0.5 mm bd is medically sustainable.[1,2,20]

(3) Stabilization

The key to form healthy regenerate is by stabilizing the new bone formed within the slot prepared. It was observed that there was enhanced endochondral bone formation due to unstable devices. Development of cartilage is not seen in case when there is direct bone formation due to secured and fixed devices.[1,2]

(4) Reinforcement period

The reinforcement period is time from the start of the distraction procedure till the withdrawal of the device. The factors which influence the time required for the consolidation period are the age of the patient and the quantity of surgical trauma. In cases of enhanced surgical trauma, increased length of latency period as well as consolidation period is recommended.[21,22,23] Photographic images are contemplated to be the excellent technique for identifying the best time for removal of the frame.

Figure 3- protocol for distraction

Alveolar distraction devices

They are broadly categorized into two types- extraosseous and intraosseous devices. Extraosseous devices can easily be placed as they have to applied on the buccal and labial side of the bone but this usually results in patient discomfort and compromised esthetics. Intraosseous devices are to be positioned internally in bone thus, making accurate placement more critical. Sufficient width of bone is required for intraosseous devices placement.

Extraosseous device

- Track-Plus distraction device

The Track-Plus device is accessible in various dimensions (1mm, 1.5mm, and 2.3 mm). Height of the tool spans from 6-15 mm. The device has a central screw along with metal plates which are welded into a central sliding device. Screw length governs the acceptable distraction height. the vertical plate helps in controlling the vector and thus reducing the amount of horizontal of bone (fig. 4).
while utilizing this tool, it is advocated to try and then withdraw before carrying out the osteotomy so as to ascertain the precise distractor position. Esthetic is compromised when used in anterior maxillary or mandibular region.[24,25]

Figure 4- Track-Plus distraction device

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Intraosseous devices

- Lead system: The Lead distractor consists of a threaded rod, a threaded transport plate, and an unthreaded stabilizing base plate (Fig. 5). in the vertical direction a passage is created in the transport segment. through this passage the threaded pin in placed into the fixed plate. clockwise rotation results in upward motion of the threaded transport plate. after every rotation 0.4 mm motion of the transport rod is seen. [26]

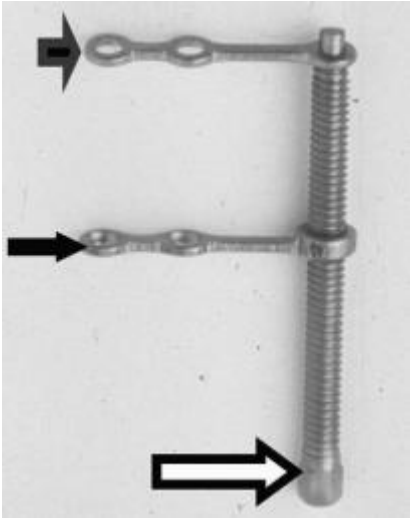

Figure 5- lead distractor

- Distraction implant: it can be used for separating bone segments as well as an implant (fig.6). Consists of a conical screw of width of 4.1mm. Sufficient diameter of bone is required for placing implant distractor.
- Advantages- requires a single surgical procedure, easier cosmetic camouflaging and reduced amount of time required from surgery to prosthesis placement.

Disadvantage- the direction of movement of distraction maybe dissimilar from the ideal position of the implants resulting in use of angulated abutments or even abandoning the implant.[27-30]

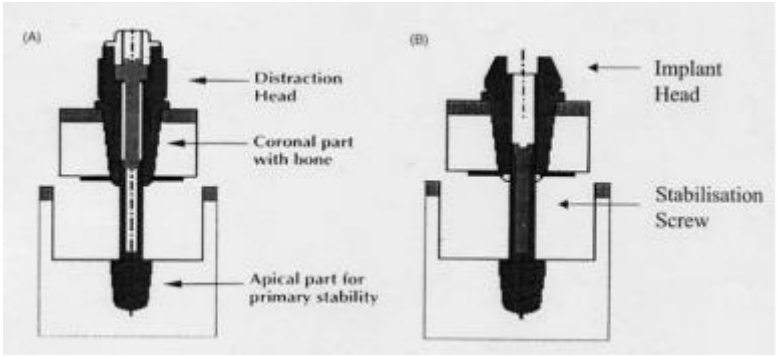

Figure 6- distraction implant

Indications

Depending upon connective tissue and bone[34]

- when height of bone is insufficient for implant placement.
- when width of available bone is deficient.
- when there is reduced height and width of bone, bone grafting maybe essential.
- when the height of the soft tissue is deficient, resulting in compromised esthetics.
- when width of soft tissue is deficient can be corrected with help of procedures like grafting.

Surgical principles

The basic surgical principles are gentle tissue handling, avoiding vertical incisions, avoid damage

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to the adjacent roots, and maintaining potent blood supply to the free segment.

The site of cut helps to direct the type of tissue that regenerates. If the cut is positioned in the attached gingiva, gingiva will regenerate whereas when it is placed in the alveolar mucosa it will regenerate mucosa.[31] To prevent dehiscence of the transport segment it is recommended to place a beveled or stepped incision (Fig.7).

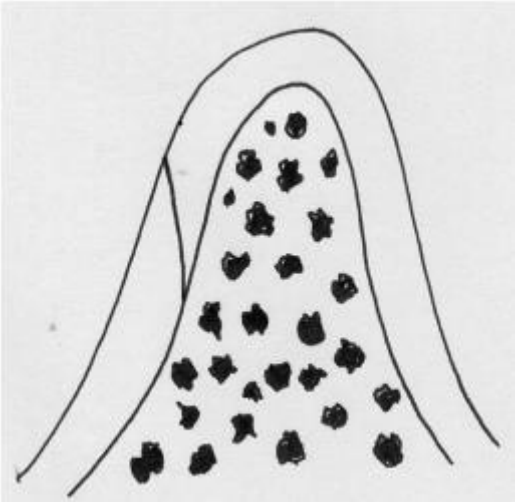

Figure 7- beveled incision can prevent dehiscence

To avoid postoperative periodontal defects, it is advocated to circumvent vertical incisions over the vertical osteotomies. Maintaining at least 1mm of bone around the roots prevent root trauma. [32,33]

The lateral vertical osteotomies have to be mapped out in such a way that they permit free motion of the transport segment. Hence the cuts should be converging towards the apical region. The vertical cuts also should be converging lingually to fend off lingual tipping (Fig.8).

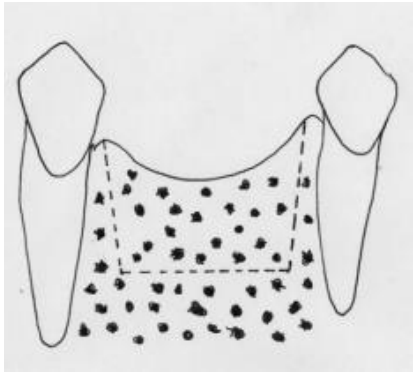

Figure 8- apically convergent lateral osteotomies

In case of atrophied mandible, angles on the inner aspect should be rounded off to reduce stress accumulation and fracture.[32]

Several methods have been proposed for distraction in posterior mandibular region. By reshaping the bone in L-shaped method helps in developing more anatomically and esthetically improved results. In the anterior area tiny upright osteotomy is prepared followed by a prolonged straight osteotomy upto the hind region. Corticotomy is generated in the hind region. The tool is positioned in the front region with the hind area functioning as a hinge (Fig. 9).

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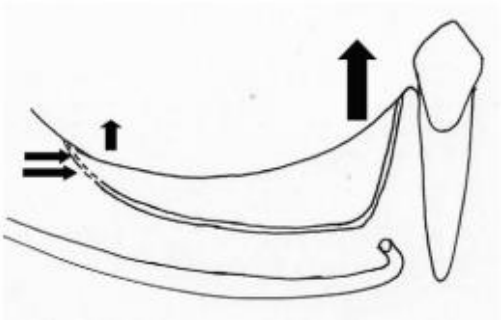

Figure 9- L-shaped osteotomy

4. Obstacles

During the course of surgery:

(1) Incapability to mobilize the transport segment: it can be due to incomplete osteotomy preparation and failure to plan diverging upright osteotomies.
(2) Encroachment of occlusion due to the device – can be prevented by use of articulated models, selection of an appropriate distraction device, trial placement before osteotomy, and modification of the device if required.

During active distraction:

(1) Improper vector of distraction
(2) Due to early binding or ossification thus diverging cuts required.
(3) Poor bone quality can result in compromised stability of the tool with fracture of transport segment.
(4) Infection.
(5) Breach of mucosa can be handled by eliminating sharp bony extremities.
(6) Dehiscence of the cut can be directed by decreasing the rate of distraction.
(7) Mandibular fracture is related to seriously atrophied mandible
(8) Due to disruption in the blood flow, resorption of the transport segment can occur.[34]

Post distraction:

Bone formation defects: CT scan as well as directly exploring the site usually helps in identify any defect in the regenerate.[35,36] Guided bone regeneration during implant placement helps in correcting buccal defects.

5. Summary

Alveolar distraction osteogenesis can play an integral role in deciding implant location. The outmost advantage of this method is the concurrent regeneration of both soft and hard tissue and reduction in treatment time. Plan for surgery should always start with imagining the final outcome so that it helps us to govern the site of connective tissue and bone insufficiency. For obtaining success of the procedure, it is mandatory to adhere to the protocols of surgery to prevent any harm to the adjoining crucial structures and continuous blood supply. Regular follow-up is required to keep a check on the distraction vector and volume considering patient's approval of the treatment plan.

References

[1] Iliazarov GA. The tension stress effect on the genesis and growth of tissues. Part I. The influence of stability of fixation and soft tissue preservation. Clin Orthop 1989;238:249 – 81.
[2] Iliazarov GA. The tension stress effect on the genesis and growth of tissues. Part II. The influence of the rate and frequency of distraction. Clin Orthop 1989;239: 263 – 85.
[3] Codivilla A. On the means of lengthening, in the lower limbs, the muscles and tissues which are shortened through deformity. Am J Ortho Surg 1905;2:353 – 69.
[4] Putti V. Operative lengthening of the femur. JAMA 1921;77:934 – 7.
[5] Abbot LC. Lengthening of the tibia and fibula. J Bone Joint Surg 1927;9:128.
[6] Ilizarov GA. The principles of the Iliazrov method. Bull Hosp Joint Dis 1988;48:1 – 11.
[7] McCarthy JG, Schreiber J, Karp N, Thorne CH, Grayson BH. Lengthening the human

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

mandible by gradual distraction. Plast Reconstr Surg 1992;89:1 – 9.

[8] Karp NS, McCarthy JG, Schreiber JS, Sissons HA, Thorne CHM. Membranous bone lengthening: a serial histological study. Ann Plast Surg 1992;29:2 – 7.

[9] Samchukov ML, Cope JB, Cherkashin AM. Biologic basis of new bone formation under the influence of tension stress. In: Samchukov ML, Cope JB, Cherkashin AM, editors. Craniofacial distraction osteogenesis. St. Louis (MO): Mosby; 2001. p. 21 – 36.

[10] Postacchini F, Gumina S, Perugia D, De Martino C. Early fracture callus in the diaphysis of human long bones. Histologic and ultrastructural study. Clin Orthop 1995;310:218 – 28.

[11] Aronson J, Good B, Stewart C, Harrison B, Harp J. Preliminary studies of mineralization during distraction osteogenesis. Clin Orthop 1990;250:43 – 9.

[12] Delloye C, Delefortrie G, Coutelier L, Vincent A. Bone regenerate formation in cortical bone during distraction lengthening. An experimental study. Clin Orthop 1990;250:34 – 42.

[13] Gaggl A, Shcultes G, Regauer S, Karcher H. Healing process after alveolar ridge distraction in sheep. Oral Surg Oral Med Oral Path Oral Radiol Endod 2000; 90(4):420 – 9.

[14] Wagner H. Operative beinverlangerung. Chirurgie 1971;42:260 – 6.

[15] De Bastiani G, Aldegheri R, Renzi-Brivio L, Trivella G. Limb lengthening by callus distraction (callotasis). J Pediatr Orthop 1987;7(2):129 – 34.

[16] White SH, Kenwright J. The timing of distraction of an osteotomy. J Bone Joint Surg Br 1990;72(3):356 – 61.

[17] White SH, Kenwright J. The importance of delay in distraction osteotomies. Orthop Clin N Am 1991; 22(4):569 – 79.

[18] Farhadieh RD, Gianoutsos MP, Dickinson R, Walsh WR. Effect of distraction rate on biomechanical, mineralization, and histologic properties of an ovine mandible model. Plast Reconstr Surg 2000;105(3): 889 – 95.

[19] Al Ruhaimi KA. Comparison of different distraction rates in the mandible: an experimental investigation. Int J Oral Maxillofacial Surg 2001;30(3):220 – 7.

[20] Kessler PA, Merten HA, Neukam FW, Wiltfang J. The effects of magnitude and frequency of distraction forces on tissue regeneration in distraction osteogenesis of the mandible. Plast Reconstr Surg 2002;109(1): 171 – 80.

[21] Fischgrund J, Paley D, Suter C. Variables affecting time to bone healing during limb lengthening. Clin Orthop 1994;301:31 – 7. H.S. Batal, D.A. Cottrell / Oral Maxillofacial Surg Clin N Am 16 (2004) 91–109.

[22] Smith SW, Sachdeva RC, Cope JB. Evaluation of the consolidation period during osteodistraction using computed tomography. Am J Orthod Dentofacial Orthop 1999;116(3):254 – 63.

[23] Urbani G, Consolo U, Lombardo G. Alveolar bone distraction for implant placement. In: Samchukov ML, Cope JB, Cherkashin AM, editors. Craniofacial distraction osteogenesis. St. Louis (MO): Mosby; 2001. p. 423 – 32.

[24] Hidding J, Lazar F, Zoller JE. Vertical distraction of the alveolar process: a new technique for reconstruction of the alveolar ridge. In: Samchukov ML, Cope JB, Cherkashin AM, editors. Craniofacial distraction osteogenesis. St. Louis (MO): Mosby; 2001. p. 393 – 400.

[25] Stucki-McCormick SU, Moses JJ, Robinson R, Laster Z, Mommaerts M, Jensen OT. Alveolar distraction device. In: Jensen OT, editor. Alveolar distraction osteogenesis. Chicago: Quintessence; 2002. p. 41 – 57.

[26] Chin M. Distraction osteogenesis for dental implants. Atlas Oral Maxillofacial Surg Clin N Am 1999;7(1): 41 – 63.

[27] Gaggl A, Schultes G, Rainer H, Karcher H. Immediate alveolar ridge distraction after tooth extraction—a preliminary report. Br J Oral Maxillofacial Surg 2002; 40(2):110 – 5.

[28] Gaggl A, Schultes G, Karcher H. Distraction implants: a new operative technique for alveolar ridge augmentation. J Craniomaxillofac Surg 1999;27(4):214 – 21.

[29] Gaggl A. Distraction implants. In: Jensen OT, editor. Alveolar distraction osteogenesis. Chicago: Quintessence; 2002. p. 119 – 32.

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

[30] Guerrero CA. Intraoral distraction osteogenesis. In selected reading in oral and maxillofacial surgery 2002; 10(1):1 – 7.
[31] Stucki-McCormick SU, Fox RM, Mizrahi RD. Reconstruction of a neocondyle using transport distraction osteogenesis. Semin Orthod 1999;5(1):59 – 63.
[32] Stucki-McCormick SU, Moses JJ. Vector and stabilization during alveolar lengthening by distraction osteogenesis. In: Jensen OT, editor. Alveolar distraction osteogenesis. Chicago: Quintessence; 2002. p. 69 – 76.
[33] Fox ME, Stephens WF, Wolford LM, el Deeb M. Effects of interdental osteotomies on the periodontal and osseous supporting tissues. Int J Adult Orthod Orthognath Surg 1991;6(1):39 – 46
[34] McAllister BS. Vertical alveolar ridge augmentation utilizing the ACE osteogenic distractor. In: Samchukov ML, Cope JB, Cherkashin AM, editors. Craniofacial distraction osteogenesis. St. Louis (MO): Mosby; 2001. p. 414 – 22.
[35] Kojimoto H, Yasui N, Goto T, Matsuda S, Shimomura Y. Bone lengthening in rabbits by callus distraction. The role of periosteum and endosteum. J Bone Joint Surg Br 1988;70(4):543 – 9.
[36] Yasui N, Kojimoto H, Shimizu H, Shimomura Y. The effect of distraction upon bone, muscle, and periosteum. Orthop Clin N Am 1991;22(4):563 – 7